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INTRODUCTION

Fire fighters are routinely exposed to hazardous noise in excess of Occupational Health and Safety Administration (OSHA) recommendations. A study by Reischl (1979) demonstrated that fire fighters are routinely exposed to impulse noises in excess of 115 dBA, and the 8-hour Time Weighted Averages (TWA) were in excess of OSHA recommendations. Tubbs (1991) demonstrated that the average fire fighter exhibited a characteristic noise-induced permanent threshold shift (PTS) that was related to length of service as a fire fighter. One might argue that much of this data is 30 years old, but Tubbs (1995) speculates that the modern mechanized equipment and machinery are getting louder, not softer.

There have been numerous studies involving fire-fighters since the early 1980's that have looked at age, length of service, gender, prior military service, and location of the fire station. Tubbs (1991) looked at fire fighters assigned to an airport fire station. While he did find that length of service was predictive of higher loss, he found no significant relationship between higher loss and assignment at the airport fire station. There are no published data that evaluate a military fire station, specifically an Air Force Base where the fire station is located adjacent to the runway and flying operations continuous 24 hours a day. A unique aspect of the military environment is the presence of civilian federal employed fire fighters who work alongside military active duty fire fighters. There are no data looking at differences in PTS between the civilian and the military fire fighters.

OCCUPATIONALLY ACQUIRED HEARING LOSS AMONG
CIVILIAN AND ACTIVE DUTY FIRE-FIGHTERS

By

ALDEN D. HILTON, B.A., M.D.


APPROVED:

FRANK I. MOORE, PH.D

ALFONSO H. HOLGUIN, M.D., M.P.H

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DEDICATION


for their love, support and patience.

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ALDEN D. HILTON, B.A., M. D.

THESIS

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OCCUPATIONALLY ACQUIRED HEARING LOSS AMONG
CIVILIAN AND ACTIVE DUTY FIRE-FIGHTERS

Alden D. Hilton, B.A., M.D., M.P.H.
The University of Texas
Health Science Center at Houston
School of Public Health, 2002

Supervising Professor: Frank I. Moore

Hearing loss in fire fighters as a result of occupational hazardous noise exposure on Air Force Bases is poorly defined. This study looks at the relationship between occupationally acquired hearing loss and employment status (active duty military versus civilian federal employee) among fire-fighters working side-by-side on the same base. While most studies have looked at prevalence, this study looks at the incidence of permanent threshold shifts in a 7 year period among all fire fighters employed at the same fire station at one of the northern-tier Air Force Bases. The strength of association between a permanent threshold shift and employment status are measured by calculating an odds ratio.

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Background

An evaluation was made of the hearing conservation program at one of the northern tier Air Force bases in the fall of 1995 based on the observation that there appeared to be a disproportionate number of civilian federally employed fire fighters who sustained PTS as compared to their military active duty counterparts.

In the Air Force, active duty and civilian fire-fighters work side-by-side in all aspects of their employment resulting in equivalent on-the-job exposure to hazardous noise. From a medical occupational surveillance perspective, no distinction is made between their employment status in determining their requirements for medical surveillance. All are treated equally.

Noise exposure in fire fighters employed at a US Air Force base comes not only from engine and siren noise, but also from aircraft noise as most fire departments are constructed on the flight-line. Aircraft noise varies from base to base depending on the type of aircraft flown and the schedule of flying. During the study period, fire fighters at the study base were exposed to aircraft noise from B-1 Bombers, B-52 Bombers, KC-135 refuelers, UH-60 Blackhawk helicopters, and T-38 trainers. The flight-line was open 24 hours per day and flying operations were continuous leading to potential exposures around the clock. The fire fighters worked 24-hour on-duty shifts with live-in facilities at the station. In this arrangement, the exposure potential to hazardous noise existed for the entire shift, frequently without advance warning. The 8-hr Time Weighted Average (TWA) noise exposure measured for this fire department is 89.6 dBA.

At the time of this evaluation, all fire-fighters received annual audiometric screening tests during a two month period each year. If a standard threshold shift (STS) was observed, they were re-tested after a 15-hour noise free period. If the STS persisted, they were tested again after a 40-hour noise free period. If the STS were still present, they were classified as having a permanent threshold shift (PTS) and were referred for formal audiometric evaluation by an audiologist or otolaryngologist to rule out disease other than noise induced hearing loss. All audiometric screening tests at the study base were administered by a civilian aeromedical technician who was trained, certified, and current in administering the test.

In this study a standard threshold shift (STS) is defined as a change for the worse in hearing threshold relative to the reference audiogram of an average of 10 dB at 2000, 3000, 4000 Hz, either ear. That is if the sum of the shifts at 2000, 3000, and 4000 Hz in the right ear or left ear exceeds 30 dB a STS has occurred.

A permanent threshold shift (PTS) is any standard threshold shift found on monitoring audiometry which is still present after a 40-hour noise-free period.

A noise-free period is defined as a period of time free of steady state noise above 72 dB or impulse noise above 120 dB peak. As a guide, a noise-free period should be free of exposure to noise loud enough to require the use of a raised voice at three feet.

A hearing profile is a method of classifying severity of hearing loss based on dB loss at specified frequencies. It is used most commonly in the Air Force to classify hearing in active duty personnel. For purposes of Air Force standards, profiles do not apply to civilian personnel. They are used in this study as an easy means of classifying degree of hearing loss. Range is: "no profile", Hearing-1 (H1), Hearing-2, (H2) Hearing-3, (H3) and Hearing-4

(H4). (AFOSH, 1991). A specific profile is given when unaided hearing loss in either ear exceeds a value listed in table 1. Having the subjects categorized in this manner allows them to be evaluated on the basis of a pre-existing hearing loss.

Table 1: Hearing Profile Definition

Hearing Profile							
	Hz	500	1000	2000	3000	4000	6000
Profile	H1	25	25	25	35	45	45
Profile	H2		35	35	35	45	55
Profile	H3	Any loss that exceeds the values noted for H2					
Profile	H4	Hearing loss to preclude safe and effective performance of duty.					

(AFI 48-123, 2000)

Literature review

In 1983, Fletcher (1983) published a report on the comparison of hearing loss among Army military engineers and their civilian federally employed counterparts working on the same post. He concluded that the civilian engineers had less hearing loss than their military counterparts. This difference he attributed to attrition of civilian engineers because of hearing loss and a likely greater exposure potential of the military engineers to hazardous noise as part of their military service.

A comprehensive review of the literature regarding susceptibility to damage from noise published in 1995 by Ward reported that eye color, gender, smoking, mental attitude toward the noise, pre-existing loss, and right versus left ear were either not predictive or not sufficiently predictive to be of value.

Henselman (1995) looked at active duty army data from the Hearing Evaluation Automated Registry System (HEARS) database and concluded that soldiers in high noise career field acquired significantly more hearing loss than those soldiers who worked in career fields that received lesser noise exposure. He also concluded that differences between the hearing threshold limits were dependent on racial group and years of military service.

An analytic cohort study by Jerger (1986) classifies well the differences in susceptibility between black and white races to noise-induced hearing loss with blacks having an apparent protective effect thought possibly due to melanin pigment in the stria vascularis.

The study by Lutman (1991) concluded that socioeconomic status (manual versus non-manual employment) was predictive of increased hearing loss.

Reischl (1981) showed that LA Fire Dept. fire fighters have greater loss with age than the general population. Tubbs (1991) looked specifically at fire fighters employed at a civilian airport fire station and concluded that the average hearing levels for frequencies 3000, 4000, and 6000 Hz were significantly increased as a function of time on the job as a fire fighter. But he found no difference between fire fighters who worked at the airport and those that did not.

Summarization of the literature suggests that age, length of service, exposure to hazardous noise, socioeconomic status, and race have a relationship with hearing loss. For this study, noise exposure and socioeconomic status, a surrogate for manual versus non-manual employment, are assumed to be the same for all subjects. Age, race and length of service are potential confounders. There is no published work evaluating military fire fighters.

Materials and Methods

Purpose

This study looked at two questions: (1) Is there an increase in hearing loss among firefighters employed at an Air Force flight line fire station? And, (2) is there an association between civilian employment status and a permanent hearing threshold shift?

Design

This study was set up as an analytic, cohort study of cumulative incidence. The database contained PTS and demographic data from 1989 through 1995 for all fire-fighters employed at the study base at the time of the study. The strength of association was calculated between a permanent threshold shift in military and civilian firefighters. This was accomplished by calculating the relative risk or odds ratio. The null hypothesis is that there is no difference in risk for PTS between civilian and active duty fire fighters. Logistic regression was employed to control for the potential confounders.

Data Collection

The study sample consisted of all firefighters employed at the study base in the fall of 1995. The data were collected by retrospective review of the medical records. The unit of study was a person with each person that sustained a PTS during the observation period counting as one case. Two individuals sustained more than one PTS during the observation period, each was counted only once.

Variables

The variables studied were: age (continuous variable recorded in years), employment status (nominal scale: civilian versus military employment), total years as a firefighter (continuous scale: recorded in years), hearing profile in 1995 (ordinal scale: range from 'no profile' to H-4), and PTS data (nominal: yes or no).

Results

Descriptive Analysis:

General Information

Of the 62 total fire fighters, 22 were civilian and 40 were military active duty. There were seven workers who sustained a PTS during the seven year study period; 6 were civilian and 1 was military.

Table 2: General information

	Total	Civilian	Military
Total Workers	62	22	40
Total with PTS	7	6	1
Incidence (unadjusted)	11 per 100	27 per 100	2.5 per 100

Age

The mean age for the entire group was 32 years with a range of 19 to 57. The mean for the civilians was 42 years with a range of 30 to 57 years. The mean age for the active duty group was 26 years with a range of 19 to 37 years. The spread of ages between the two groups was almost exclusive of each other.

Table 3: Age versus employment status

AGE	Total	Civilian	Military
Mean	31.68	42.36	25.80
Standard Deviation	9.67	6.98	4.48
Min	19	30	19
Max	57	57	37
95% CI of mean	29.22 - 31.33	39.27 - 45.46	24.36 - 27.23

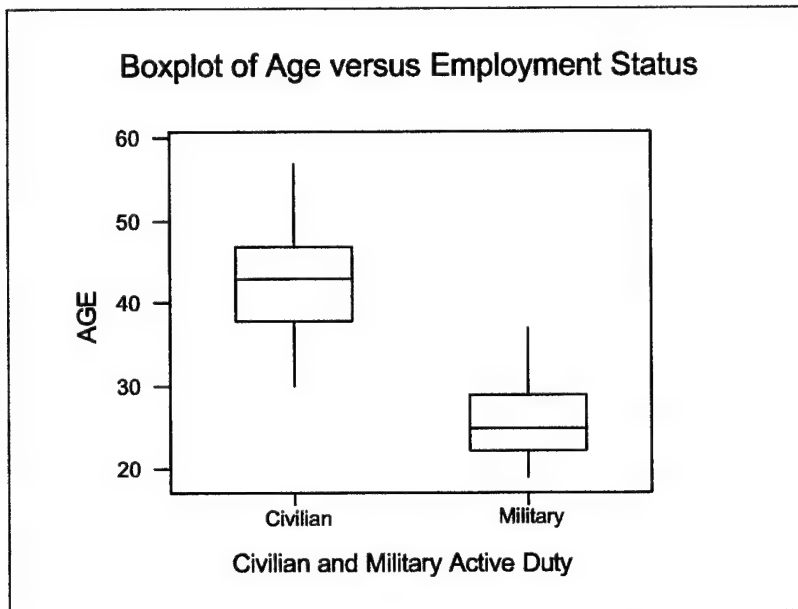


Figure 1: Boxplot of Age versus Employment Status

Hearing Profile (Pre-existing Hearing Loss)

The degree of pre-existing hearing loss is represented by the hearing profile of the subjects. The majority of the total group (74%, n=46) had relatively normal hearing (no profile), while only one forth (26%, n=16) had some degree of hearing loss (H1, H2, or H3). There was no PTS among fire fighters with no pre-existing hearing loss (no profile). And while the numbers are small, the incidence of PTS appears to increase as the degree of hearing loss increases (see table 4). This apparent increase in incidence also parallels the increase in mean age for the groups.

The civilian group had 12 employees with some degree of pre-existing hearing loss. (prevalence = 550 out of 1000) The active military group had 4 with some pre-existing hearing loss. (Prevalence = 25 per 1000) (see table 5)

Table 4: Age versus Degree of Pre-existing Hearing Loss

AGE vs. Profile	NONE	H1	H2	H3
(n)	46	6	4	6
Mean age	29.13	32.67	44.75	41.50
Standard Deviation	8.43	11.11	6.7	6.09
Min age	19	21	38	31
Max age	57	47	54	48
95% CI of mean	26.63 - 31.63	21.01 - 44.33	34.09 - 55.41	35.11 - 47.89
Number with PTS	0	1	2	4
Prevalence (Unadjusted)	0 per 100	17 per 100	50 per 100	67 per 100
	0 per 100	44 per 100		

Table 5: Employment Status versus Degree of Pre-existing Hearing Loss

Status vs. Profile	NONE	H1	H2	H3
Civilian	10	3	4	5
Active Duty	36	3	0	1

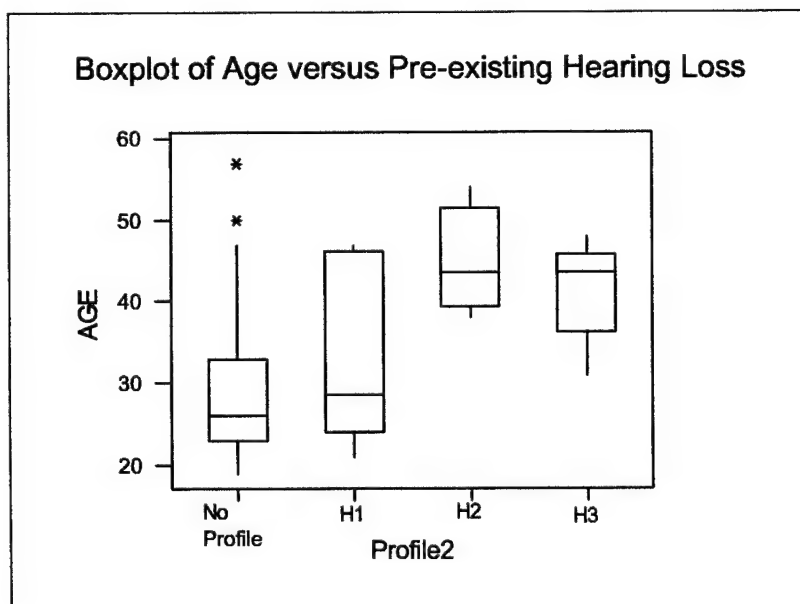


Figure 2: Boxplot of Age versus Pre-existing Hearing Loss

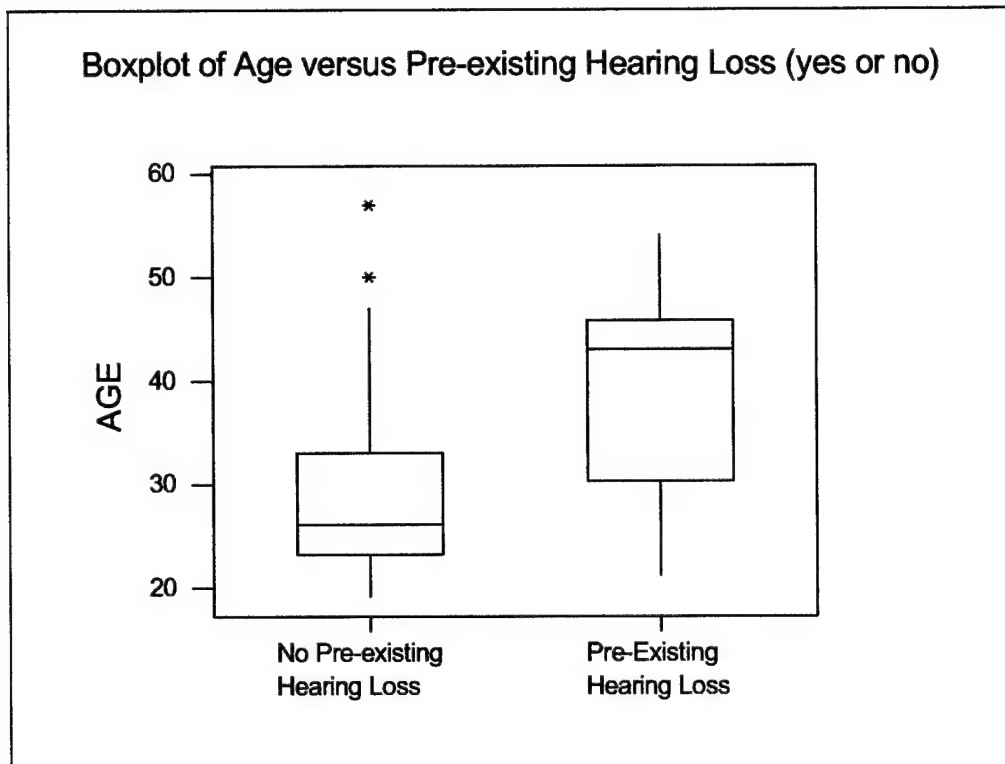


Figure 3: Boxplot of Age versus Pre-existing Hearing Loss (dichotomous: yes or no)

Length of Employment

The mean length of employment for the entire group was 7.5 years with a range of 1 to 22 years. The civilian mean length of employment was 12 years with a range of 1 to 22 years, while the active duty was 5 years with a range of 1 to 15 years. The pattern shows that civilian employees on average had worked as a fireman twice as long as the military active duty.

Table 6: Years on job versus employment status

YEARS ON JOB	Total	Civilian	Military
Mean	7.47	11.59	5.20
Standard Deviation	5.79	6.57	3.78
Min	1	1	1
Max	22	22	15
95% CI of mean	6.00 - 8.94	8.68 - 14.50	3.99 - 6.41

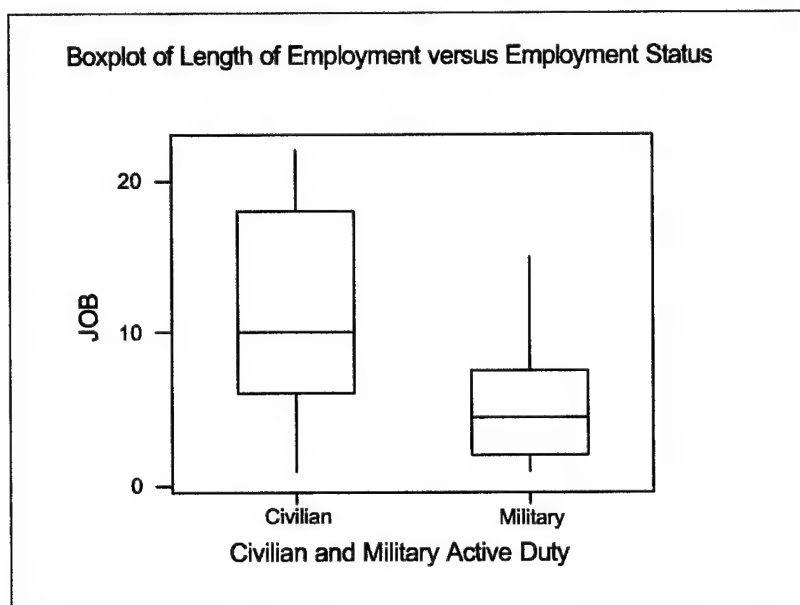


Figure 4: Boxplot of Length of Employment versus Employment Status

Statistical Analysis:

Question 1: Is there an increase in hearing loss among firefighters employed at an Air Force flight line fire station?

Table 7: Unadjusted Binary Logistic Regression

Binary Logistic Regression (unadjusted) Question #1				
Variables		Odds Ratio	95% Confidence Interval	p-value
Hearing Loss	Age	1.12	1.04 – 1.20	0.001
Hearing Loss	yrs on job	1.25	1.11 – 1.42	0.000

Table 8: Adjusted Binary Logistic Regression (Pre-existing hearing loss versus age and years on job)

Binary Logistic Regression (adjusted) Question #1				
Variables		Odds Ratio	95% Confidence Interval	p-value
Hearing Loss	Age	1.03	0.93 – 1.14	0.557
	yrs on job	1.21	1.01 – 1.43	0.036

At the 95% confidence level, both 'age' and 'years on job', when compared individually (table 7) with 'hearing loss', were statistically significant. However, when they were compared together (table 8), only 'years on job' was significant with an odds ratio of 1.21. So, for every 1 year increase of service as a fire fighter, an individual is 1.21 times more likely to have sustained a hearing loss. Or stated differently, for every 1 year that an individual works as a fire fighter at the study base, the odds of him sustaining a permanent decrement in hearing increases by 1.21 each year.

Question 2: Is there an association between employment status and PTS?

Table 9: Unadjusted Binary Logistic Regression

Binary Logistic Regression (unadjusted) Question #2				
Variables		Odds Ratio	95% Confidence Interval	p-value
PTS	Empl. Status	14.62	1.63 – 131.39	0.017
PTS	Age	0.87	0.79 – 0.96	0.006
PTS	yrs on job	0.77	0.66 – 0.91	0.002
PTS	Hearing Loss	0.16	0.06 – 0.43	0.000

Table 10: Adjusted Binary Logistic Regression

Binary Logistic Regression (adjusted)				
Variables		Odds Ratio	95% Confidence Interval	p-value
PTS	Empl. Status	0.60	0.00 – 95.77	0.842
	Age	0.96	0.71 – 1.31	0.796
	Yrs on Job	0.86	0.65 – 1.14	0.303
	Hearing Loss	0.20	0.06 – 0.65	0.008

At the 95% confidence level, ‘employment status’, ‘age’, ‘years on job’, and ‘prior hearing loss’ when compared individually with a ‘PTS’ were statistically significant. However, when considered together, only ‘prior hearing loss’ was significant at the 95% confidence level. This supports the observation made earlier that the incidence of PTS appears to increase as the degree of hearing loss increases.

Discussion

The purpose of this investigation was to answer two questions: (1) Is there an increase in hearing loss among firefighters employed at an Air Force flight line fire station? And, (2) is there an association between civilian employment status and a permanent hearing threshold shift? The effects of age, length of employment, pre-existing hearing loss, and employment status were examined.

This study was not without limitations. The database used for this investigation contains only PTS data. It did not contain actual audiogram results. Thus, the audiometric results cannot be standardized against ISO standards. The records were compared against others in the database, but it was difficult to compare them to any other group. Additionally, of the 62 records in the database, only one was female, and only two were not Caucasian, so this investigation was unable to address race or gender. This database had a relatively small sample size – only 62 subjects. Park and Dudycha (1974) reported that multiple regression requires 15 subjects per predictor to achieve sufficient power. Initially, this study was to include the relationship between PTS and the degree of existing hearing loss, i.e. hearing profile 1, 2, and 3. But this would require a minimum of 105 subjects. So profile was examined as a single variable, leaving 4 variables to be studied requiring a minimum of 60 subjects. Since all subjects were from the same base, the results should be applied with caution to other fire fighter populations at other bases. The profile system as used in this study had measurement error since the database only reflects the profile status at the time of the record review (1995) and not at the time of the PTS. So, an individual with 'no profile' could sustain a PTS and cross the threshold to an 'H-1 profile'. This would be noted as an H-

1 Profile on the record review. In this dataset, there was only one individual that sustained a PTS who is categorized as an H1 profile. In spite of these limitations, the results do provide information not previously documented.

First, when adjusted for age, there was a statistically significant risk of NIHL related to length of employment as a fire fighter. An investigation looking at audiometric results standardized for age could measure the degree of hearing loss compared against another population. This study was only able to adjust for age statistically, a less precise measure. However, the hearing loss found could not be mathematically explained by age, only by length of employment. This corresponds to results published by Tubbs (1991) where he concluded that the average hearing levels for fire fighters employed at a civilian airport fire station were significantly increased as a function of time on the job as a fire fighter.

Second, there was no significant association between employment status, civilian and active duty, and the incidence of permanent threshold shifts. While this may seem intuitive, the initial descriptive data with the civilian PTS incidence of 270 per 1000 and the military PTS incidence of 25 per 1000 are unusually lopsided. And, the logistic regression model was unable to explain the pattern based on age or length of service. Additionally, all of the PTS's occurred in individuals that had some degree of existing hearing loss. Why this apparent disparity. It may be due to the sample size being too small either to find a significant relationship or to remove the disparity. Additionally, this investigation was not able to examine the non-occupational hazardous noise exposures. The individuals with PTS may be the ones with significant non-job related noise exposures. Ward (1995) discusses the inherent differences in susceptibility or predisposition to hearing loss that exist in any population. Perhaps these 7 subjects are more susceptible to NIHL than their co-workers.

Another potential confounder was one of compliance with prescribed hearing protection measures. While this air base has a well developed, formal hearing conservation program, the level of compliance with protective practices varies from individual to individual based on their personal level of motivation. Motivation to protect one's hearing may be affected by issues such as expediency or urgency, apathy, laziness, desire for disability compensation, or lack of confidence in the protective equipment. It would be interesting to ask these questions again with HEARS data from several Air Force Bases and with a larger sample size.

Conclusions

When adjusted for age, there was a statistically significant risk of NIHL related to length of employment as a fire fighter. This is consistent with previously conducted studies that show a positive association between hearing loss and length of employment. (Tubbs 1991) For every 1 year that an individual worked as a fire fighter at the study base, the odds of him sustaining a permanent decrement in hearing increased by 1.21 each year.

There was no demonstrable association between employment status and incidence of permanent threshold shift. These results do not allow for rejection of the null hypothesis which states that there is no difference in risk for PTS between civilian and active duty fire fighters when the data is adjusted for age, length of service and degree of pre-existing hearing loss. The risk of PTS was significantly associated with a pre-existing hearing loss.

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VITA

Major Alden D. Hilton was born on the [REDACTED] in Port Arthur, Texas. He graduated from Port Neches-Groves High School in Port Neches, Texas in 1984 at the same time earning his Eagle Scout and Order of the Arrow in the Boy Scouts of America.

Following graduation, he attended Lamar University in Beaumont, Texas for one year. He then took a two-year leave of absence while serving as a missionary for the Church of Jesus Christ of Latter Saints in Yucatan, Mexico. He returned to Lamar University in Beaumont, Texas where in 1990 he earned a Bachelor of Arts degree with "high honors" in Spanish, with minors in chemistry and biology. He attended the University of Texas Medical Branch in Galveston on a Uniformed Services Health Professions Scholarship receiving his Medical Doctor degree in 1994. In June of 1995 he completed his internship at the 375th Medical Group, Scott AFB, Illinois. In September, 1995, Major Hilton completed the Aerospace Medicine Primary course. His first operational assignment in the United States Air Force was as a flight surgeon to the 28th Medical Group, Ellsworth AFB until 1998. He served as Chief, Flight Medicine Flight and Chief of Aerospace Medicine from March 1996 through August 1998. In September, 1998, Major Hilton received a change of assignment to the 37th Bomb Squadron, Ellsworth AFB as Chief Medical Officer. During this assignment he deployed for 2 months to Thumrait, Oman in support of Operations Desert Thunder and Desert Fox. He continued to serve as the Commander, Flight Medicine Flight. Major Hilton has logged over 300 hours as a flight surgeon in 14 different types of military aircraft. He is married to the former [REDACTED] of Vidor, Texas. Together, they have 5 children: [REDACTED] He joined the Masters program in Public Health in July, 2002 at The University of Texas Health Science Center at Houston, School of Public Health, San Antonio Satellite Program.

This thesis was typed by Alden D. Hilton.